SCHOFIELD BARRACKS MILITARY RESERVATION, KU TREE RESERVOIR, DAM
Kalakoa Stream
East Range
Wahiawa Vicinity
Honolulu County
Hawaii

HAER No. HI-81-A

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Department of the Interior
1849 C Street, NW
Washington, D.C.

HISTORIC AMERICAN ENGINEERING RECORD

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Location:	Kalakoa Stream (Tributary to the South Fork of Kaukonahua Stream) East Range, Schofield Barracks Military Reservation Wahiawa Vicinity City and County of Honolulu Hawaii USGS 7.5 minute series topographic map, Waipahu, HI 1998 Universal Transverse Mercator (UTM) coordinates: 04.605640.2377530
Date of Construction:	1922-1925
Engineers & Builders:	Office of the Quartermaster General and Office of Chief of the Fourth Construction District
Present Owner:	U.S. Army
Present Occupant:	U.S. Army (training area)
Present Use:	Reservoir drained and abandoned, dam not in use.
Significance:	The Ku Tree Reservoir dam is significant as a major element of the Ku Tree Reservoir and as a good example of a hydraulic earth-fill dam constructed in Hawaii during the period 1900-1940. Designed to impound water for irrigation, domestic use, and other conservation purposes, the dam is typical of its period in its use of materials, method of construction, craftsmanship, and design.
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Date:	June 2008

For additional information see the main report on the Ku Tree Reservoir (HAER No. HI-81), as well as the individual reports on the other related structures in this complex (HAER Nos. HI-81-B, HI-81-C, and HI-81-D).

DESCRIPTION

The Ku Tree Reservoir Dam is a hydraulic earth-fill structure. Its description is largely based on sheets 4 and 5 of the 1924 reservoir drawings. Its measurements are approximately 550' in length and 90' high, with a crest width of about 30'. It is oriented on a northwest-southeast axis, with the reservoir to the northeast. The upstream side of the dam has a three-to-one (ratio of the horizontal to vertical) slope with hand-placed stone rip-rap running from the embankment crest (elevation 1,085 feet) down to elevation 1,060. The downstream face of the dam also follows a three-to-one slope, with its originally grassed surface now overgrown with mature trees, shrubs, and staghorn fern. Ten-foot wide berms are situated on this face at the 1,055- and 1,025-foot elevations, but are somewhat difficult to discern today, due to the heavy overgrowth and erosion. The two faces of the dam contain approximately 175,000 cubic yards of earth. Both exterior surfaces are heavily overgrown, and the upstream rip-rap is no longer intact, although the materials are readily evident. Foxholes, used in combat training, have been dug into the dam in multiple locations.

The dam has homogenous embankments and a redwood diaphragm core wall. The core wall is composed of three four-inch layers of California redwood, one horizontal layer of 4” x 12” boards encased on either side by a vertical layer of 4” x 12” boards. The butt joints on the exterior layers are covered by waling, also consisting of horizontal 4” x 12” boards. The core wall is set in a reinforced-concrete cutoff wall. Sheet 5 shows that this was designed to be 3'-0" in width at its top, transitioning to 2'-6" in width at its bottom. The depth measurements of this cutoff wall vary, because the builders were instructed to excavate “to suitable bearing.” The cutoff wall was designed with a grooved top, into which the core wall was set and grouted in place. The cutoff wall ties into the hillsides at either end of the dam, and on the east side extends over to, and ties into, the spillway.

A concrete-lined, segmental-arched drain tunnel, measuring 6'-0" in height and width, penetrates the dam at its base, discharging drained waters from the valve tower to the downstream section of the original stream at the 980-foot elevation. The smooth face of the tunnel on the downstream side has the date 1923 imprinted above its segmental arched opening. The tunnel has approximately two feet of silt covering its floor.

The dam was designed to impound the waters of the Kalakoa Stream and store the waters from this stream and its tributaries, as well as the waters deriving from Canon Reservoir. At spillway crest the reservoir had a capacity of 293 million gallons, or 900 acre-feet, of water, and a surface area of approximately 32 acres. The basin behind the dam is irregular in shape, varying in width from 0.5 to 0.75 miles, and is approximately 1.5 miles in length. Its drainage area covers approximately 0.83 square miles, with three tributaries feeding into the basin (U.S. Army Corps of Engineers, 1984: 1-3). The Ku Tree drainage basin lies entirely within military lands, originating on the precipitous leeward slopes of the Koolau Mountain range, with elevations ranging from 995' at the dam to 1,747'.

The dam retains its integrity, and there have been no alterations or additions made to it. However, the embankments have not been maintained and are now overgrown, and the upstream rip-rap facing has been altered by military exercises and vegetation growth.

HISTORICAL CONTEXT

Planning for the Ku Tree Reservoir began in 1919, following a decision to locate the dam at a narrow opening in a gulch, about 200 feet upstream of a protruding shoulder of the adjoining hill, which caused the Kalakoa Stream to make an almost-right-angle turn. Four site alternatives were considered: the selected site, one further downstream, and two further upstream. A table on Sheet 3 of the original drawings shows that selection considerations included the amount of material needed to construct the dam and the resulting capacity. The selected site apparently was one that was a compromise between the site that had greatest reservoir capacity and that which required the least amount of fill for the embankments.

In 1921 Congress appropriated the necessary funds to construct the reservoir. Construction started in October 1922. Because of the distance between Washington D.C. and Hawaii, construction and supervision of the dam was undertaken by the construction service of the Quartermaster Corps' Fourth Construction District, Honolulu. The final elevations and sections for the cutoff wall and redwood core were drawn in December 1923, and plans for the dam were drawn and traced in June and July of 1924, well after construction had started on the dam. These 1924 plans deviated very little from the 1919 conceptual-phase drawings. The principal changes involved the replacement of a proposed reinforced concrete revetment on the upstream side of the embankment with hand-placed rip-rap and the addition of two ten-foot wide berms on the downstream side of the dam.

The dam is a good example of a hydraulic earth-fill dam in Hawaii. There are 125 extant earth-embankment dams in Hawaii that are 25' or more in height or have an impounding capacity of 50 acre-feet or more. Of these, 107 were constructed between 1885-1940, with the overwhelming majority built by the sugar industry to irrigate their plantation fields. Earth-fill dams are the most commonly constructed dams, as they utilize materials in their natural state which require a minimum of processing. In addition the foundation requirements for earth-fill dams are less stringent than for concrete dams.

The Ku Tree Reservoir was one of seven earth-fill reservoirs in the state designed primarily to furnish water for domestic use. With its 90' height, the Ku Tree Reservoir dam was the third tallest earth-fill dam constructed in the islands prior to World War II. Only the Alexander Dam (113', built 1930) and Puu Lua Dam (105', built 1925) on Kauai are higher. The Ku Tree Reservoir had a capacity of 293 million gallons, or 900 acre-feet, of water at spillway crest. Of the pre-World War II reservoirs, only the Nuuanu 4 (1910) and Lake Wilson (1906) reservoirs have a greater capacity on Oahu, and the only other reservoirs to retain more acre-feet are the Alexander (1930), Koloko (1890), and Kapaia (1910) reservoirs on Kauai (Division of Water and Land Development, 1992). As such the Ku Tree dam was one of the larger earth-fill dams constructed in Hawaii. However, a number of larger hydraulic earth-fill dams remain throughout the American west, most notably the Fort Peck Dam in Montana, which was constructed as a Works Progress Administration project by the Army Corps of Engineers between 1933-1940. Standing 250' in height and 10,578' in length, the Fort Peck Dam remains the largest hydraulic earth-fill dam in the United States (U.S. Army Corps of Engineers, Omaha District, 2008).

The Ku Tree dam's design and method of construction were typical of its time. It is classified as a diaphragm hydraulic earth-fill dam. As the classification indicates, the dam is composed of soil as its primary material, which was laid down in layers by the hydraulic method of construction, and uses a thin diaphragm of impermeable material, in this instance a redwood core wall, to form a water barrier.

The hydraulic method of dam construction was developed in the American West, having emerged out of the technologies of hydraulic mining. In order to employ this method, an abundant deposit of clayey soil had to exist in an area near the proposed dam site, and a sufficient supply of water, capable of generating five to ten cubic feet of water per second, had to be available. The water, pumped under pressure, would be used to erode the deposit of soil and then carry it by way of flumes to the dam construction site, where the suspended sediment would be laid down in courses with lateral flumes distributing the sluiced materials. Thus the material to construct the embankments of the dam could be transported to the dam site in a cheap and effective manner. A hose shooting ten cubic feet of water per second could remove and relocate approximately 2,000 to 4,000 cubic yards of soil in twenty four hours. This method offered a 20-25% savings over the ordinary method of construction, which used sweepers and carts. In the case of the Ku Tree dam, the builders found it more expedient to blast the red and yellow clayey volcanic soil loose with dynamite and black powder, prior to subjecting it to the water (*Honolulu Advertiser*, September 14, 1924: 7).

Anthony Chabot, a mining engineer, was the earliest person known to utilize this method of dam construction, having employed it to make additions to the Oakland Reservoirs in the 1870s. The Tyler, Texas reservoir dam (1894), designed by engineer J. M. Howells, is the earliest known dam to be constructed totally by this method. The prominent Los Angeles-based engineer James Dix Schuyler utilized this method in Hawaii when constructing the Waialua Plantation Reservoir in 1907, which is now known as Lake Wilson. With few exceptions, hydraulic earth-fill dams were not constructed after 1940, as they were supplanted by rolled-earth dams, which were made possible by the development of larger, more economical earth-moving equipment. The present rolled-earth technique has proven to be not only more reasonable in price than hydraulic but also allows less seepage and provides a better structural performance. With the hydraulic method it was difficult to control the density of the placed materials. As hydraulic earth-fill dams' embankments tended to be loose in relative density, they have displayed a greater potential for slope movement during seismic events, which was vividly demonstrated in the 1971 San Fernando, California earthquake (ASCE Task Committee, 2000: II-10, Committee on the Safety of Existing Dams, 1983: 213-214; U.S. Department of Reclamation, 1977; and Smith, 1972).

The use of a redwood core wall in the Ku Tree dam was also typical of its time and place. As with the hydraulic method of construction, the redwood core wall in earth-fill dams was developed in the western United States, as redwood proved to be an inexpensive and durable core material, which when dampened expanded to prevent excessive seepage into the downstream embankment. It was used previously in Hawaii in the Nuuanu 4 Reservoir dam and also the dam for Waialua plantation.

The design of the dam was also typical of its period, closely following the recommended standards set forth in the civil engineer Edward Wegmann's book -- *Design and Construction of Dams*, which was first published in 1899, and was in its 7th edition in 1922. Wegmann recommended the crest of the dam should have a width of 10' to 30', and the Ku Tree dam's width at the crest is about 30'. Similarly, the embankments on each side have a 3:1 slope, while Wegmann recommended an upstream slope between 2:1 and 3:1, and a downstream slope of 1.5:1 to 2.5:1. He also indicated, for earth-fill dams of considerable height (60-100 feet), the downstream embankment should be broken by one or more berms placed about 30' apart vertically (Wegmann, 1907: 223). The Ku Tree dam has two ten-foot-wide berms, which are situated at the 1,055- and 1,025-foot elevations.

The dam's use of hand-placed rip-rap, a facing of randomly placed stone, on the upper 25' of its upstream side was typical for its period in terms of materials, craftsmanship, and method of construction. Hand-placed rip-rap proved to be the most economical and successful material to prevent erosion, scour, or sloughing of an embankment. It extended from the anticipated low-water line to the crest. Hand-placed rip-rap ideally utilized rectangular stones 15-24 inches thick placed on a 12-18 inch layer of broken, 2"- to 3"-diameter stones. Although the pattern of the stones has been disrupted by vegetation growth and other factors, the drawings clearly indicate hand-placed rock. The added effort of hand placement, as opposed to dumped rip-rap, is an indication of this period in the history of dam construction.

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PROJECT INFORMATION

See main report for Ku Tree Reservoir, HAER No. HI-81.

Figure 1: Section Thru Dam. Job No. S3603, Portion of Sheet 4, dated June 1924.

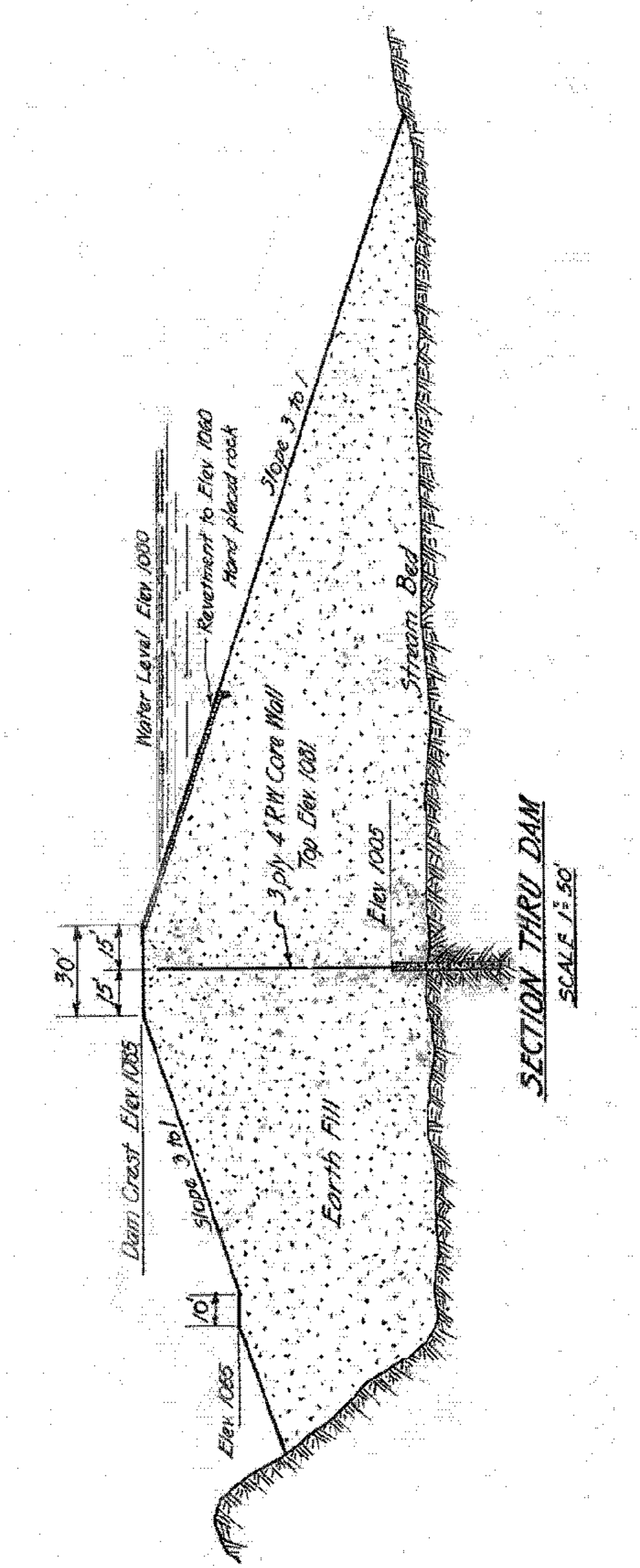

Figure 2: Details of Redwood Core Wall. Job No. S3603, Portion of Sheet 5, dated Dec. 29, 1923

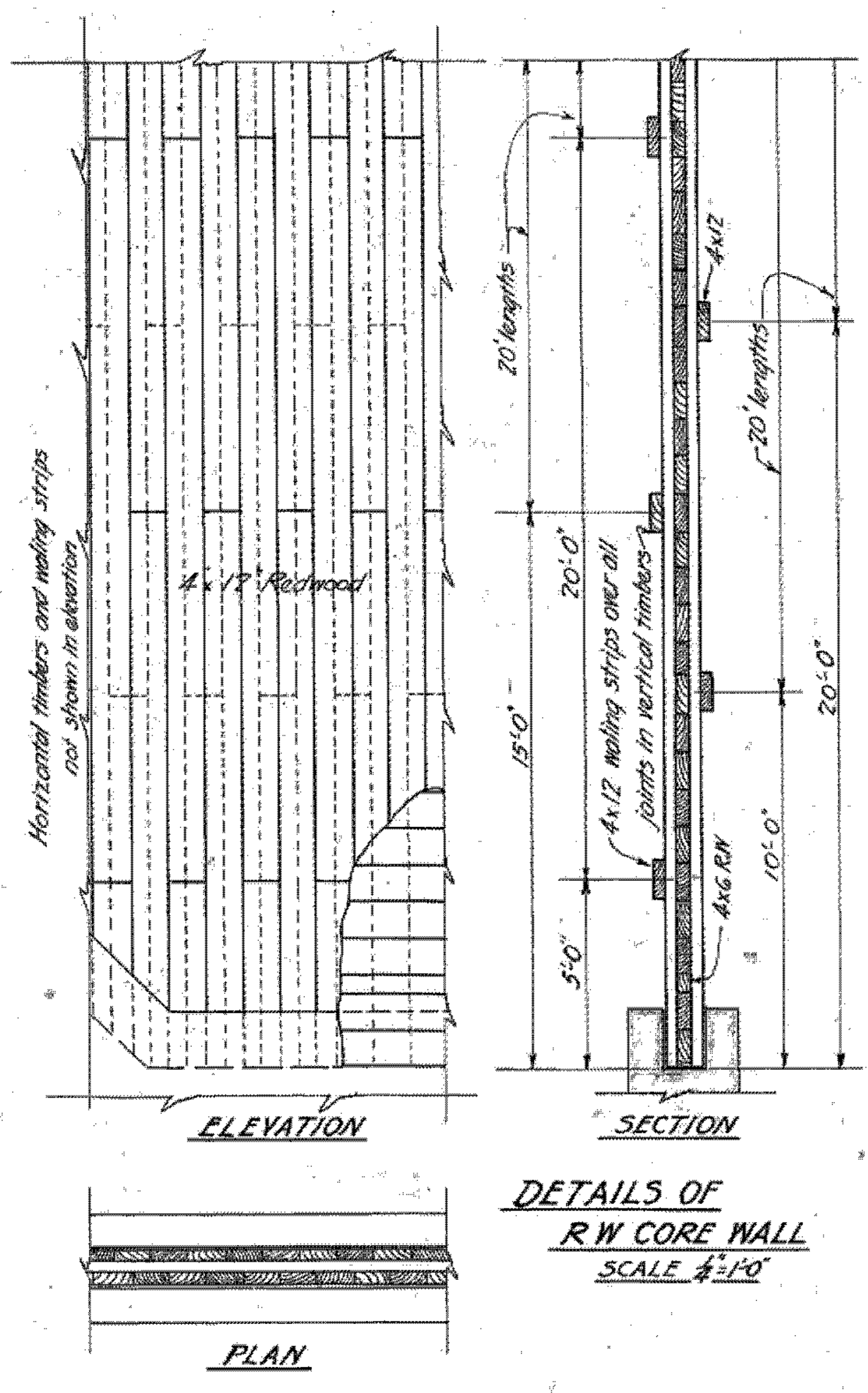

Figure 3: Ku Tree Dam, 1924. (Tropical Lightning Museum, Schofield Barracks, Hawaii, Historical photograph 87.76.01-29)

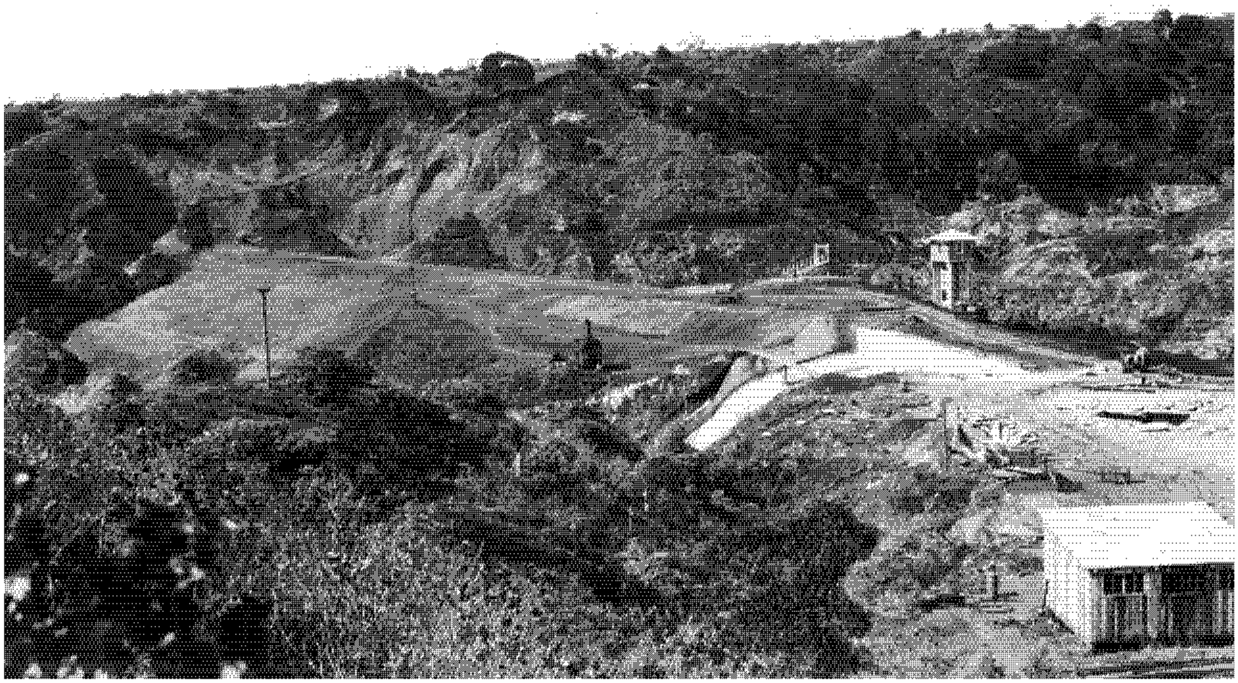

Figure 4: Ku Tree Reservoir, with stepped face of dam in foreground, Feb. 15, 1932. (National Archives II, Still Photo Section, photo order #18-AA-51-43)